MACS Concept and Project Status

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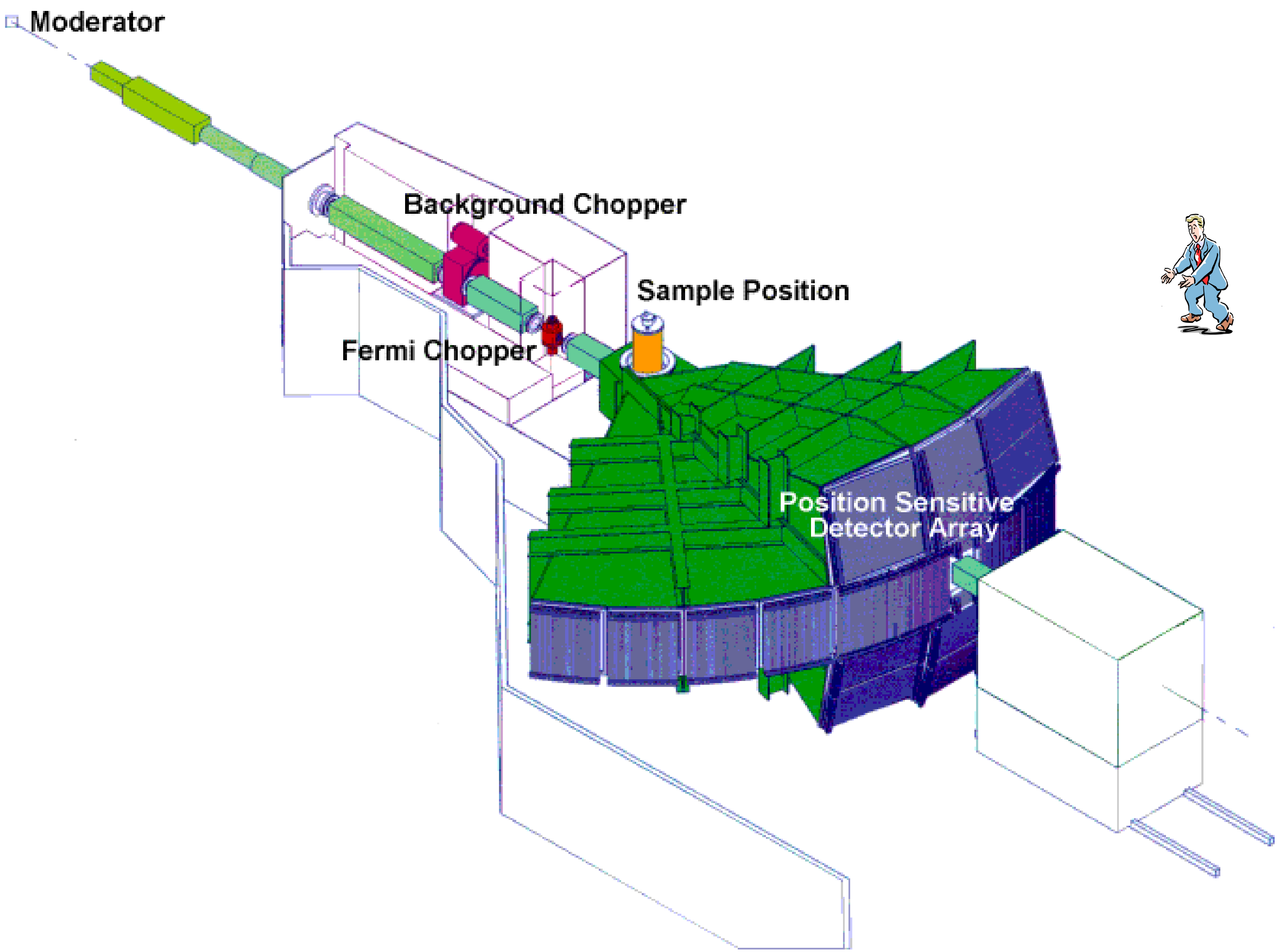
- Making best use of CW source
- MACS-imizing incident flux
- MACS-imizing detection efficiency
- From concept to reality

Goals in Neutron Spectroscopy

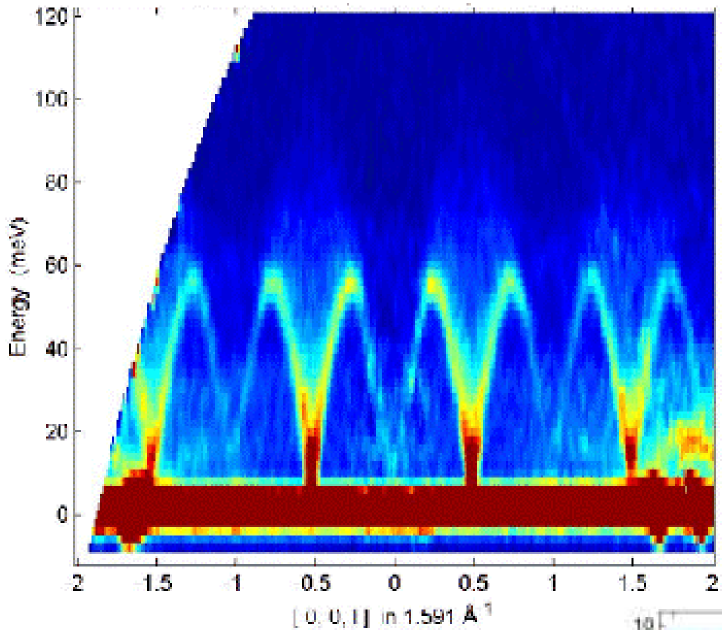
- A technique with a future
  - Unique information about dynamic correlations
  - Model independent access to interaction strength
  - Access microscopic structure of dynamic systems
- Limited scope on current instruments
  - Need cm^3 sized crystals
  - Need weeks of beam time
- Increased sensitivity will broaden impact
  - Smaller samples earlier in new materials cycle
  - Parametric studies as in diffraction
  - Comprehensive surveys for tests of theory

The Spallation Neutron Source

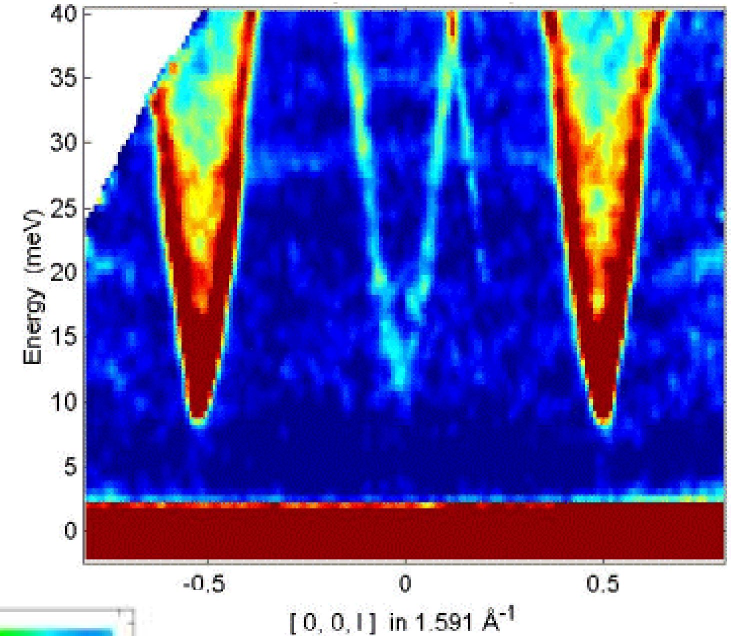
MAPS Spectrometer at ISIS

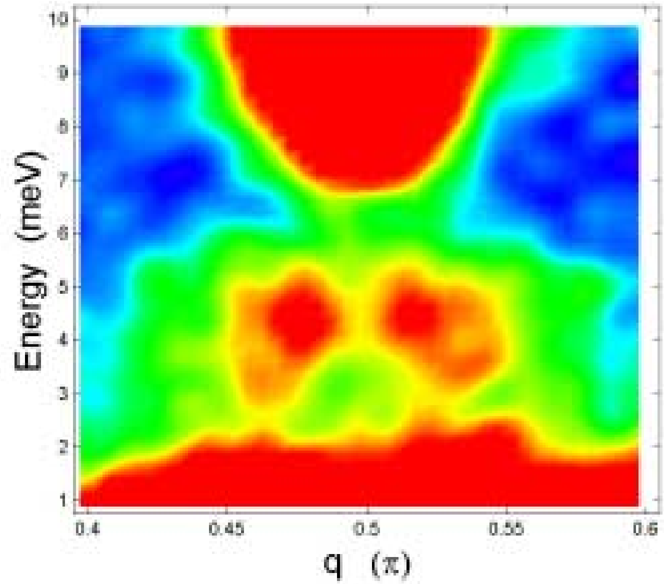


Spectroscopy from MAPS



$KCuF_3$
A. Tennant et al.





$Y_{2-x}Ca_xBaNiO_5$
Y. Chen et al

Advantages of TAS like instrumentation

- Use Bragg optics to focus incident beam
- Use Bragg reflection to polarize beam
- Select probed energy range
  at fixed resolution and sensitivity
- Flexibility in resolution for given "kinematic footprint"

TAS sensitivity scales with CW flux so are best implemented at Reactor based neutron source`

Why cold neutrons and double focusing

- Q and E resolved spectroscopy requires

$$\Delta E \approx 0.1 J \qquad \Delta Q \approx 0.1 a^{-1}$$

- Energy scale J varies more than length scale a

Lattice	Compound	J (meV)	a (Å)
3D Cubic S=5/2	$La_{0.7}Pb_{0.3}MnO3$	8.8	3.9
2D Square S=1/2	La_2CuO_4	132	5.4
2D Kagomé S=3/2	$KCr_3(OH)_6(SO_4)_2$	1.2	3.7
2D Kagomé S=3/2	$SrCr_9Ga_3O_{19}$	10	2.9
1D S=1/2 chain	$Cu(C_6D_5COO)_2 \cdot 3D_2O$	1.5	3.2
1D S=1/2 chain	$KCuF_3$	35	3.9
1D S=1 chain	NENP	4.1	5.2
1D S=1 chain	$AgVP_2S_6$	58	2.9

- To probe a range of materials must vary

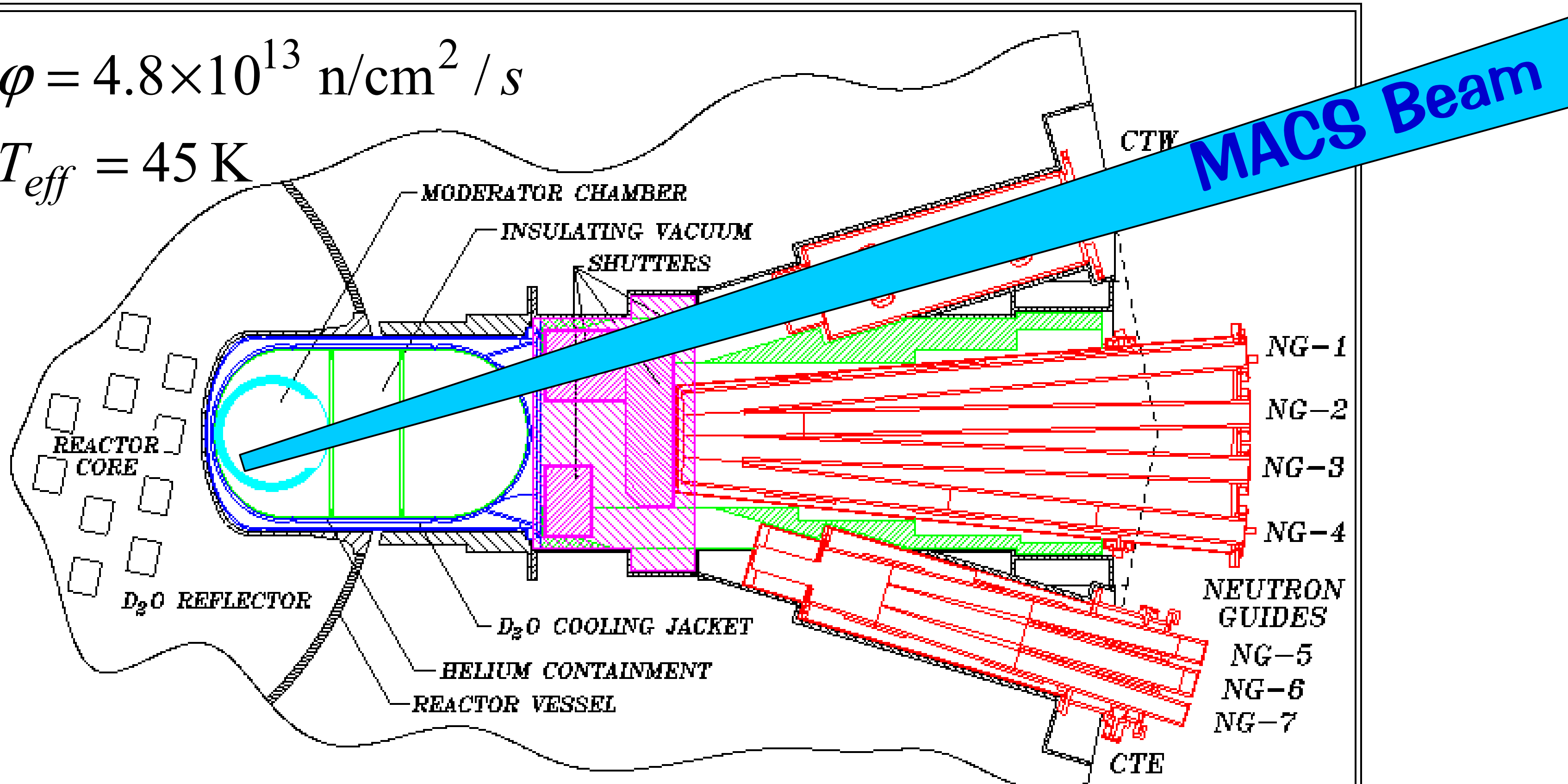
10^{-2} meV $< \Delta E < 10$ meV keeping $\Delta Q \approx 0.05\, A^{-1}$

- To probe hard matter with low energy scales
  - Reduce E_i. Cold source provides the flux
  - Increase angular divergence before and after sample

NCNR Liquid Hydrogen cold source

$$\varphi = 4.8\times10^{13}\ \mathrm{n/cm^2}\ /\ s$$

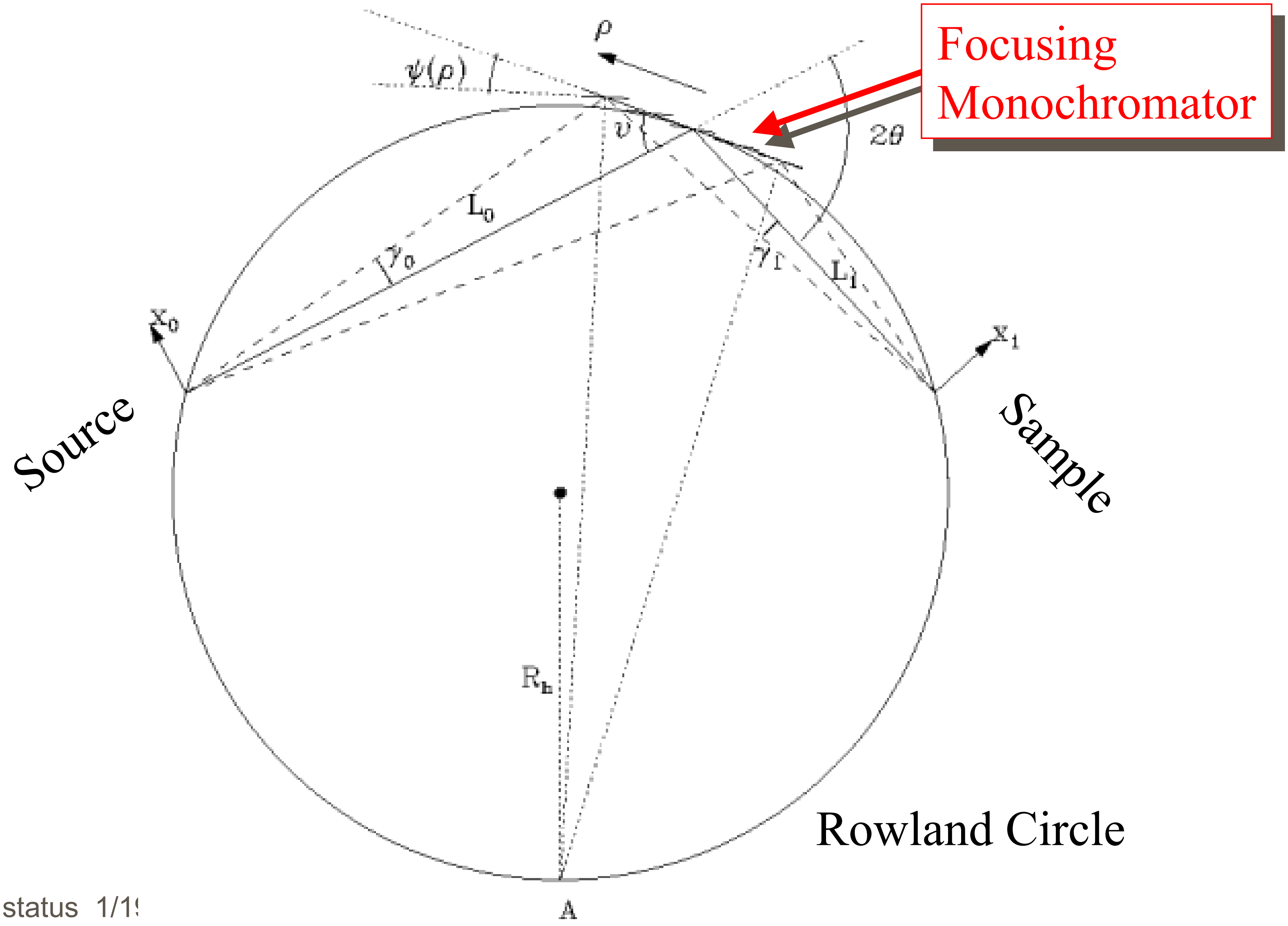
$$T_{eff} = 45\ \mathrm{K}$$

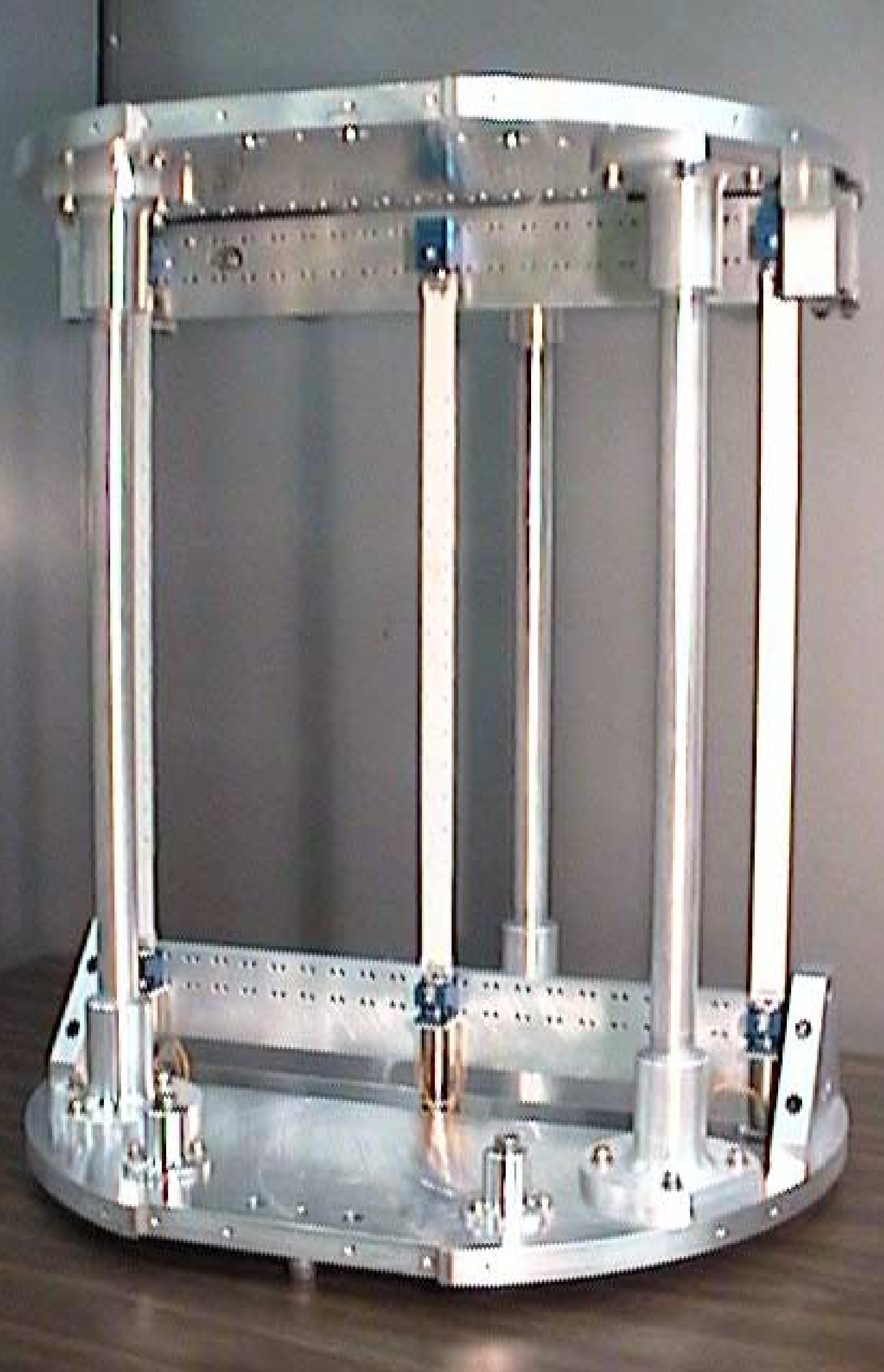


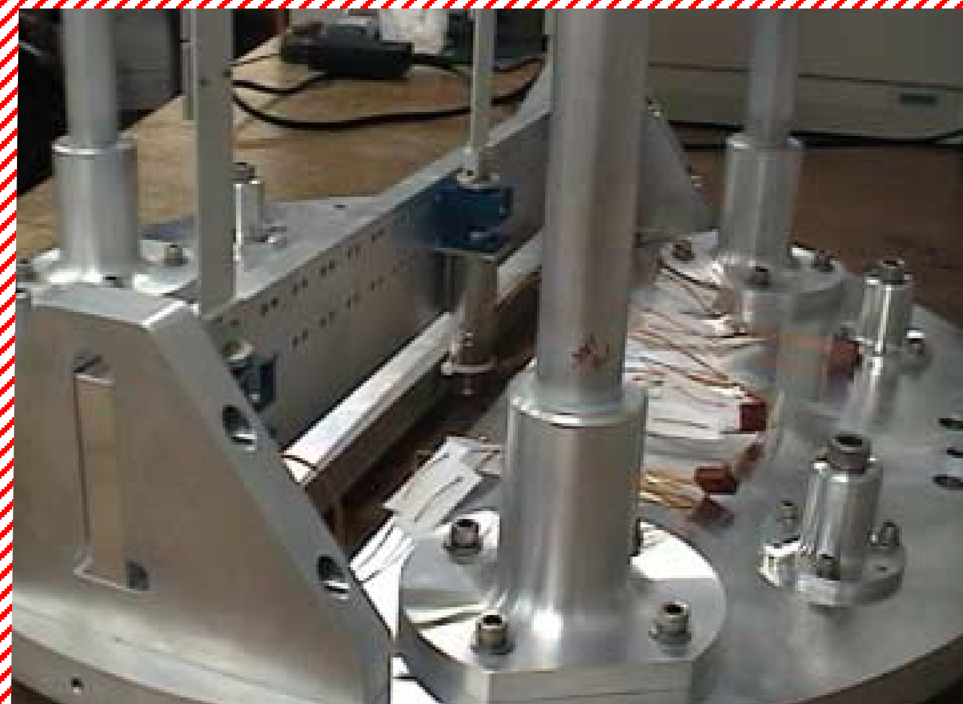
NIST HYDROGEN COLD SOURCE

New cold source to be installed in 2001 will double flux

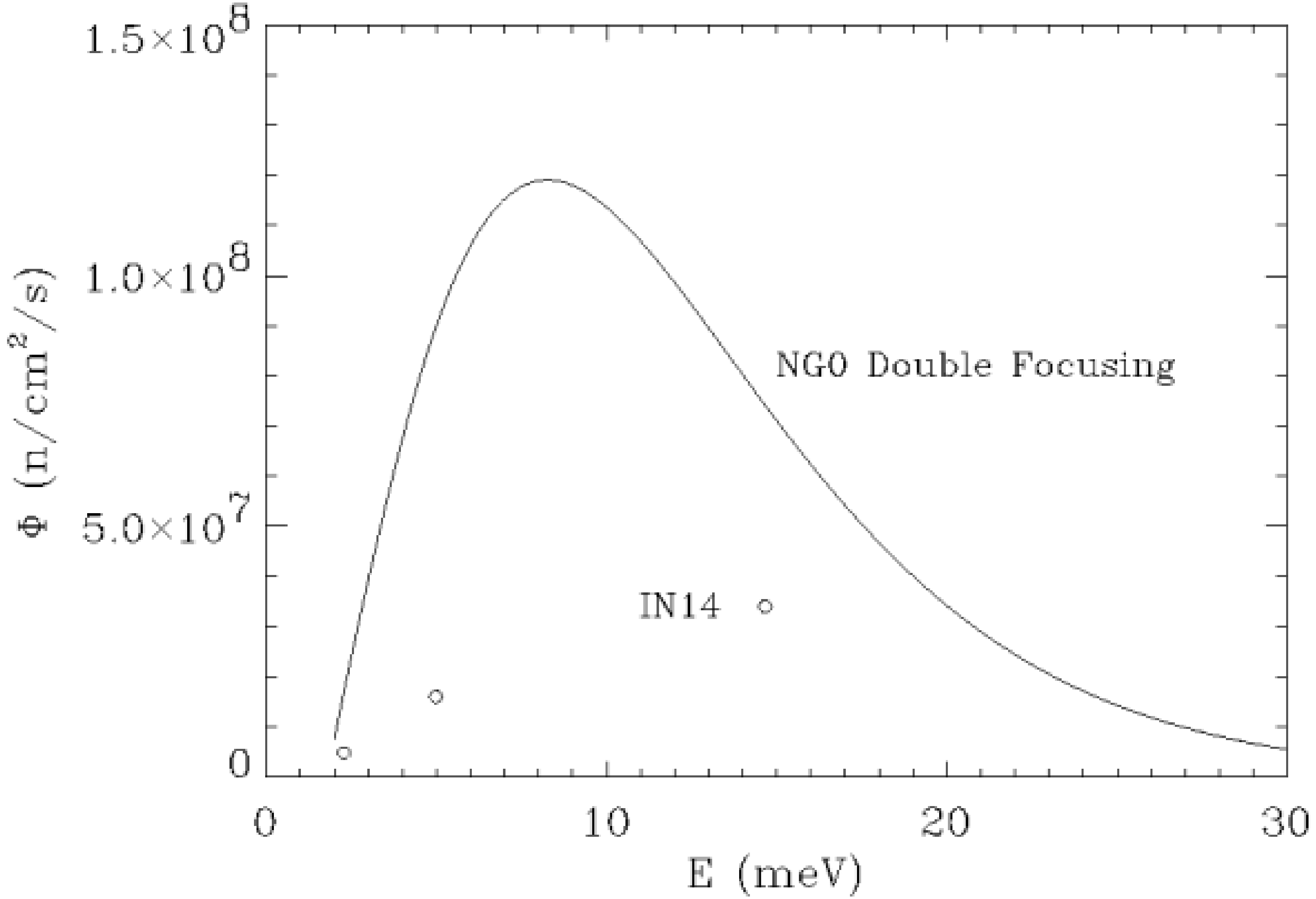
Bragg focusing





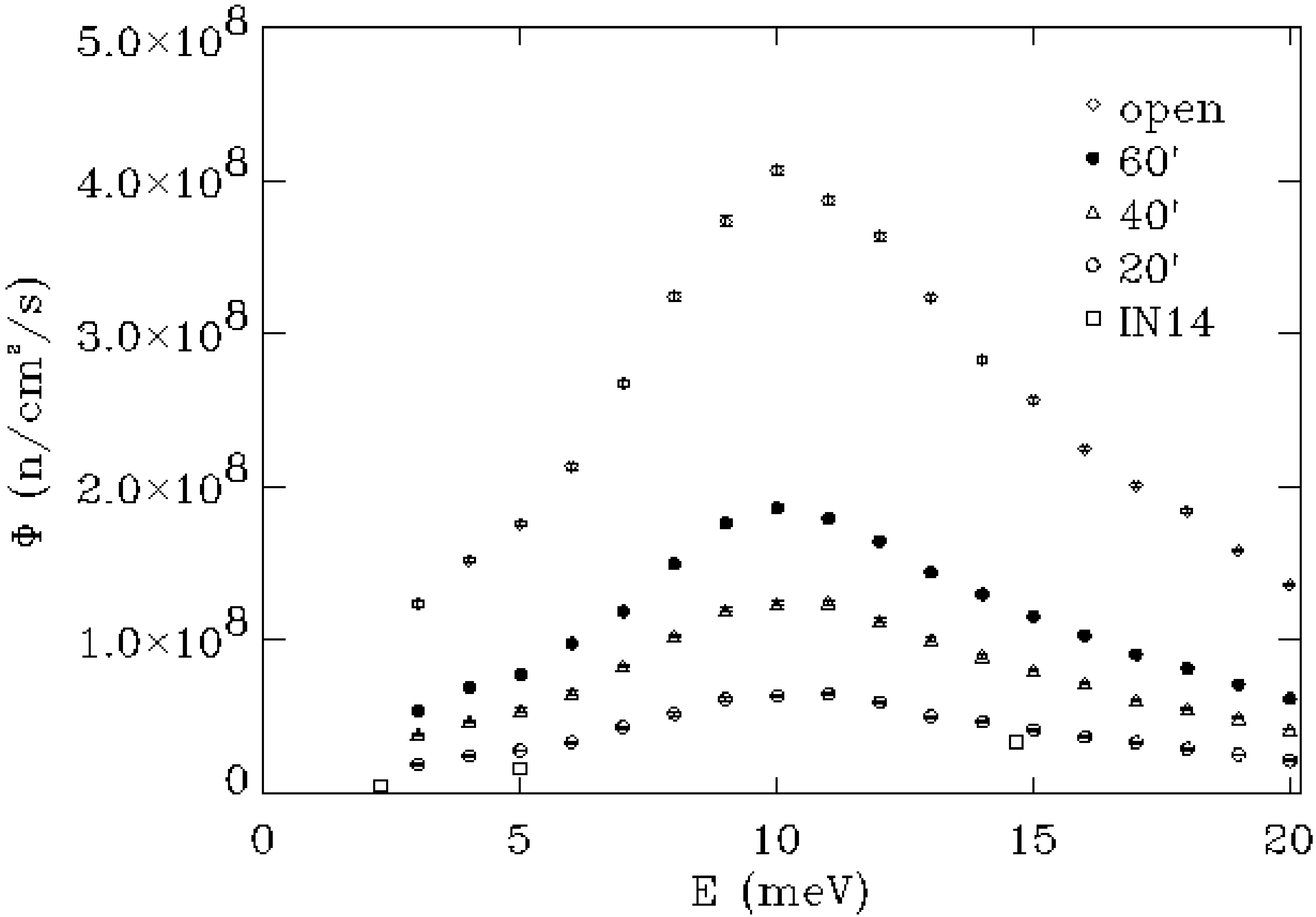


Projected performance analytical approximation



C. Broholm, Nucl. Instr. Meth. A 369 169-179 (1996)

Monte Carlo Simulation of MACS

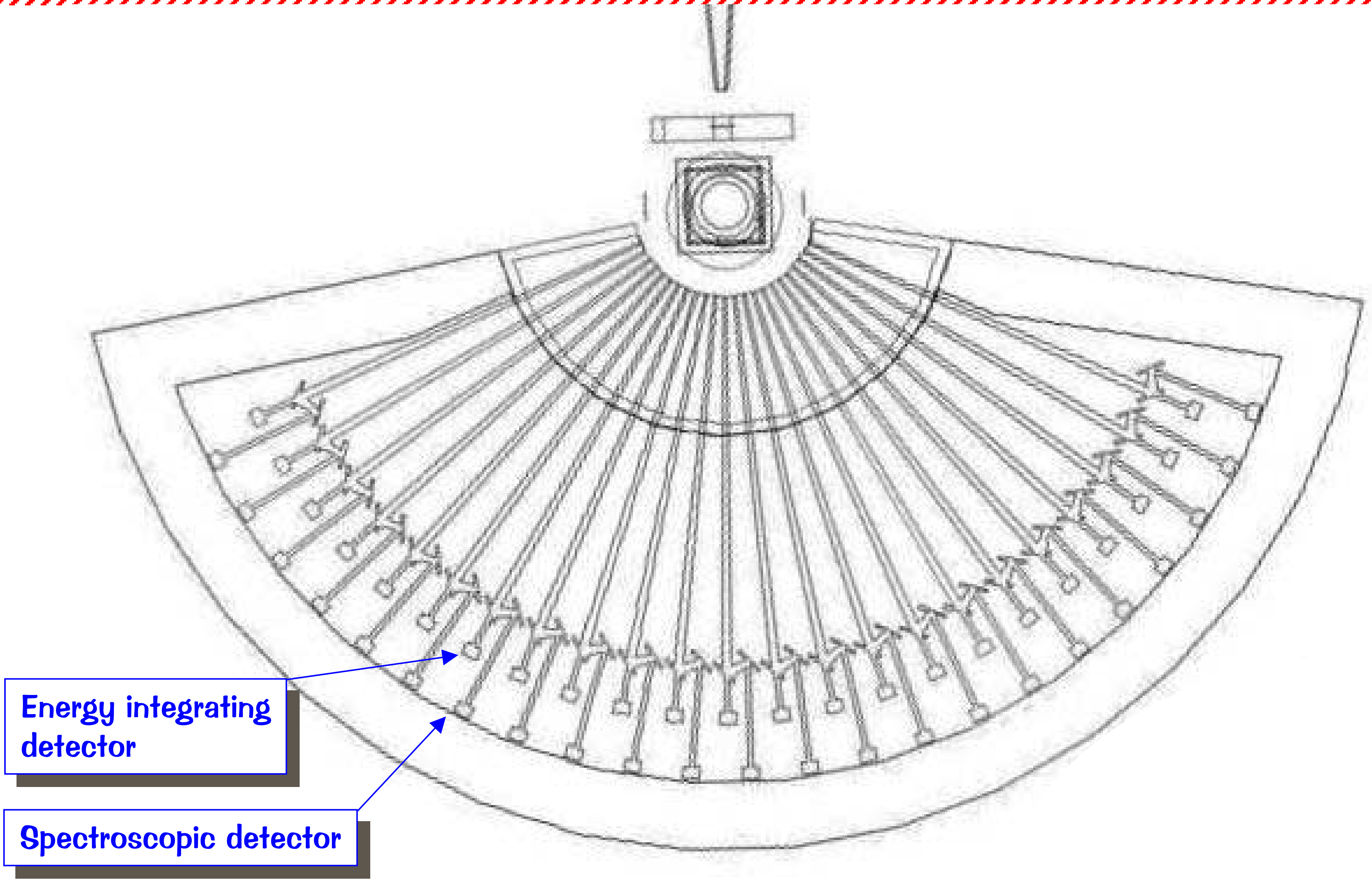


Y. Qiu and C. Broholm to be published (2000)

Increasing Efficiency of the detection system

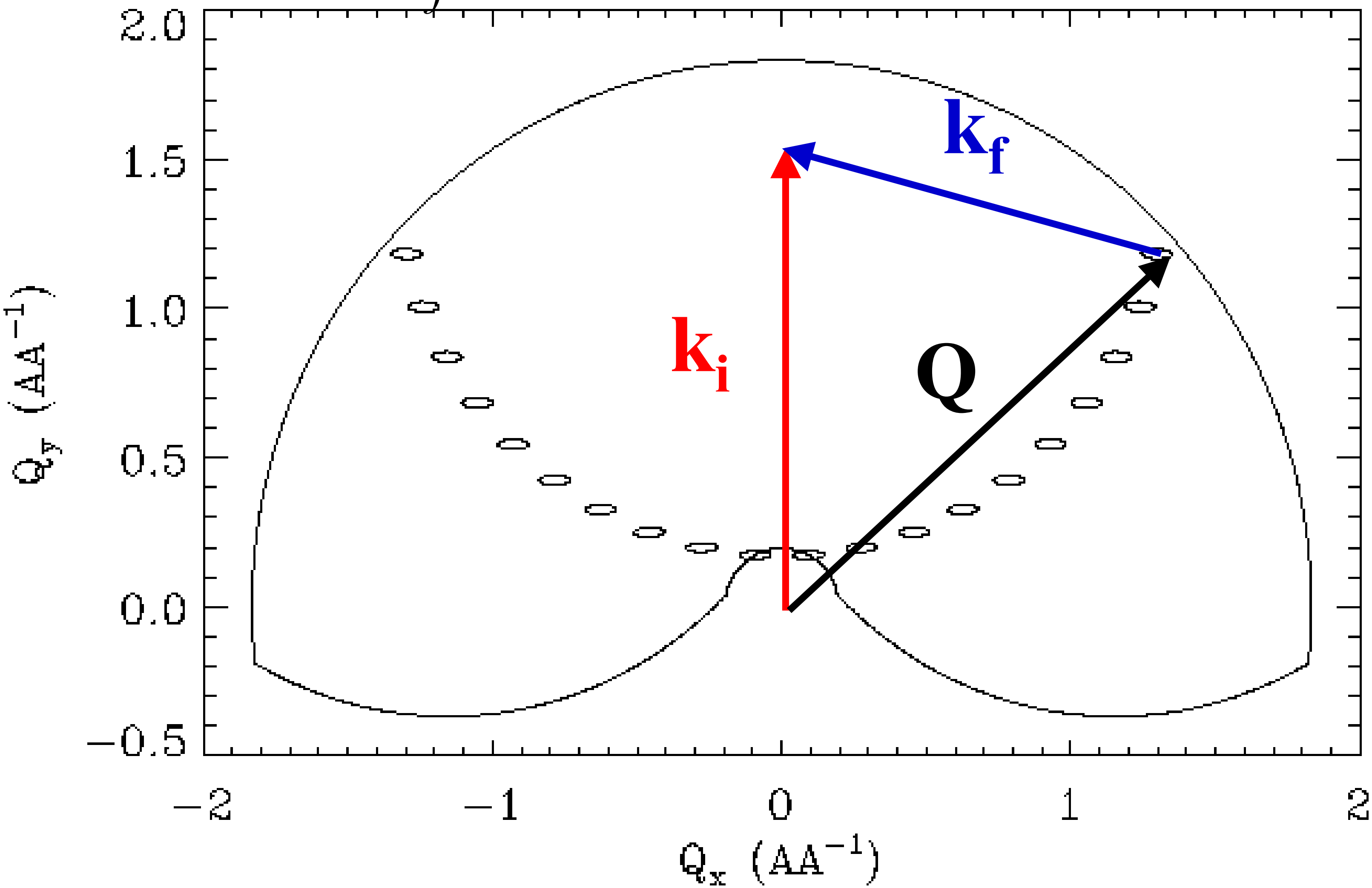
- Maximize solid angle of detection
- Maintain the virtues of TAS
  - Ability to select single energy
  - Ability to vary resolution at fixed E_f
  - High signal to noise ratio
- Detect neutrons "not at E_f"
- Need a practical solution

Double bounce analyzer array

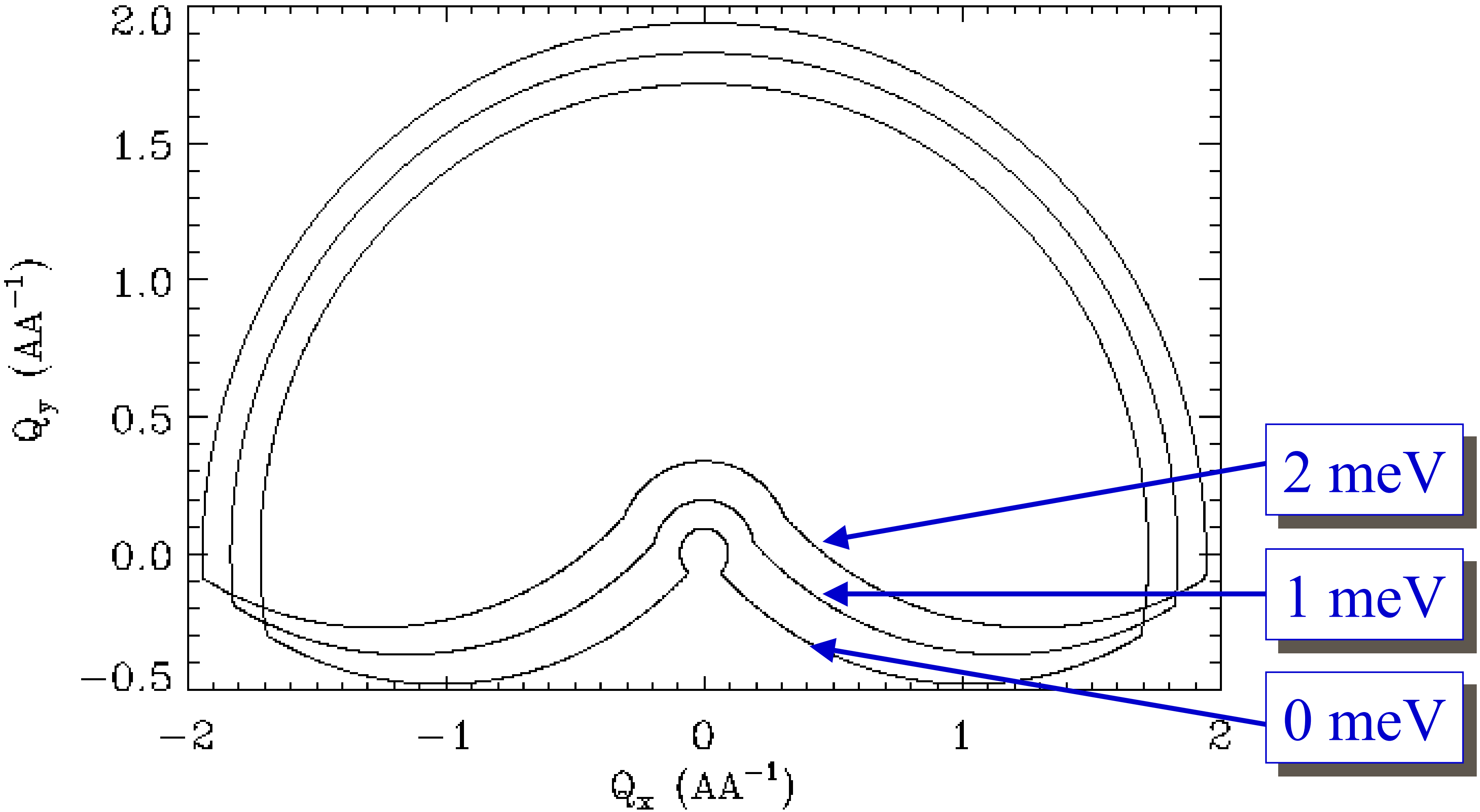


Constant energy transfer slice

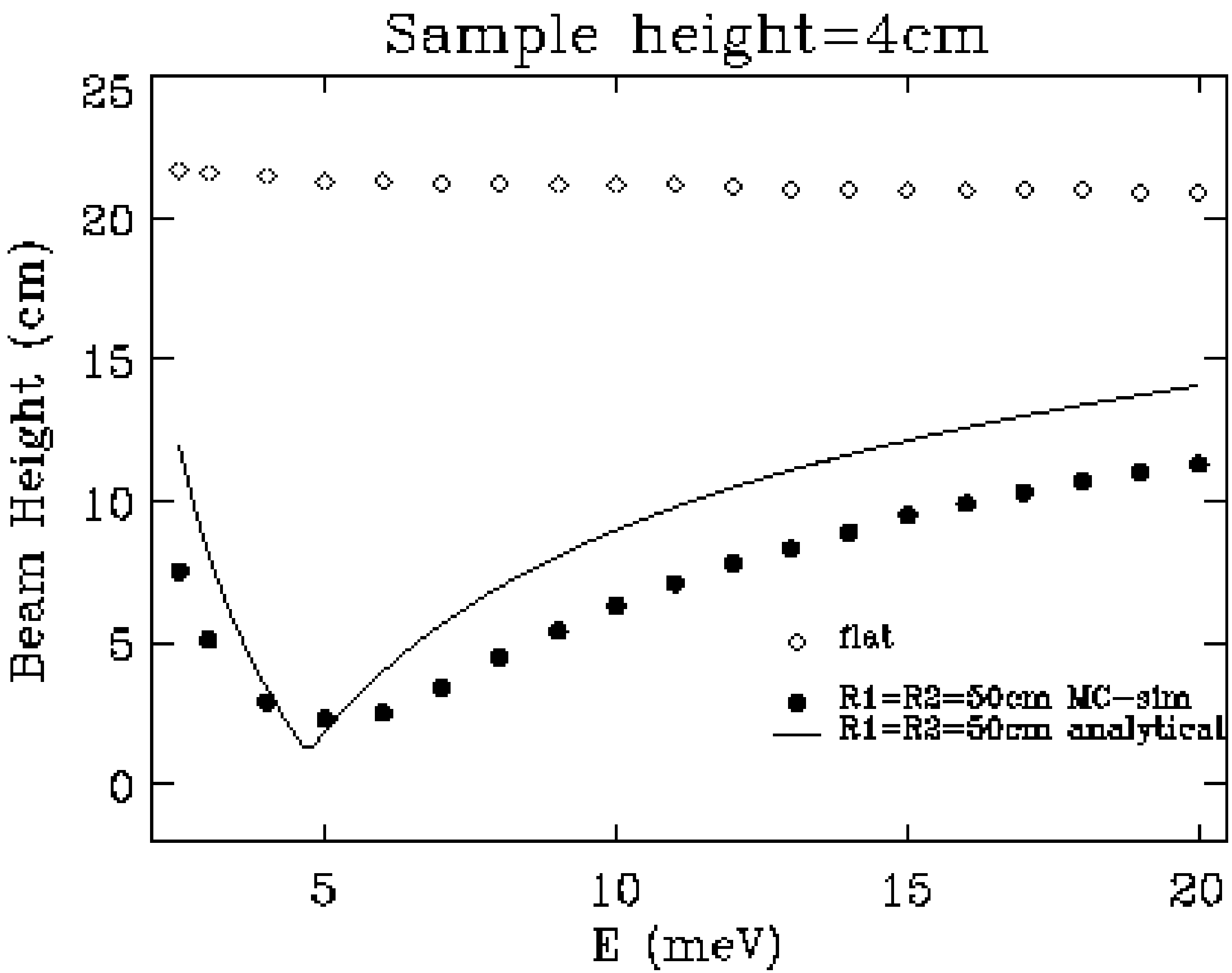
$$E_f = 3.7\,\text{meV} \quad \hbar\omega = 1\,\text{meV}$$



Assembling slices to probe Q-E volume



Fixed vertical focusing of analyzers



Double analyzer is "compound lens" → efficient vertical focusing

The history of MACS

1993 Discussions about the possibility of a "sub-thermal" TAS on NGO
1994 Analytical calculations show efficacy of double focusing at NGO
1995 Initiate JHU/NIST project to develop conceptual design
1998 Top level specification for monochromator completed
1998 JHU/NIST project starts to develop Doubly Focusing Monochromator
2000 Christoph Brocker starts engineering design

Scientific Program for NGO spectrometer

- Expanding the scope for Inelastic scattering from crystals:
  - 0.5 mm^3 samples
  - impurities at the 1% level
  - complete surveys to reveal spin-wave-conduction electron interactions
  - extreme environments: pressure and fields to tune correlated systems
- Probing short range order
  - solid ionic conductors, spin glasses, quasi-crystals, ferroelectrics, charge and spin polarons, quantum magnets, frustrated magnets.
- Weak broken symmetry phases
  - Incommensurate charge, lattice, and spin order in correlated electron systems
- Excitations in artificially structured solids
  - Spin waves in magnetic super-lattices
  - magnetic fluctuations in nano-structured materials

MACS development team

Overall instrument design

Paul Brand	NIST
Christoph Brocker	NIST
Collin Broholm	JHU
Jeff Lynn	NIST
Mike Rowe	NIST
Jack Rush	NIST
Yiming Qiu	JHU

Shielding Calculations

Charles M. Eisenhauer NIST

Focusing Monochromator

Steve Conard	JHU
Joe Orndorff	JHU
Tim Reeves	JHU
Gregg Scharfstein	JHU
Stephen Smee	UMD

Conclusions

- Large solid angle access to NCNR cold source enables a unique cold neutron spectrometer.
- MACS employs Bragg optics to focus the beam and provide $> 10^8$ n/cm^2/s on the sample at 0.2 meV resolution.
- The MACS detector concept offers the versatility, resolution, and low background of a TAS with 20 times greater data rate.
- The highly efficient constant E mode of MACS will provide a unique capability for probing the structure of fluctuating systems.
- MACS will be complementary to the DCS and future SNS TOF spectrometers because of its unique data collection protocol
- NSF partnership is needed to realize the potential and make the unique capabilities available to widest possible cross section of the US scientific community